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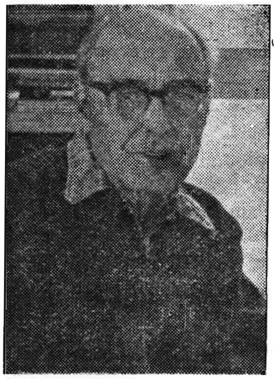

MESOZOIC TETRAPODS AND THE NORTHWARD MIGRATION OF INDIA

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INTRODUCTION

It is generally although not universally the opinion among geologists who have given their attention to the world-wide problem of plate tectonics and continental drift, that peninsular India was at one time a part of the great super-continent of Gondwanaland, and that during the course of geologic history it broke away from its parent land mass to drift northeastward, eventually to collide with the Asiatic mainland. The collision, it is thought, was a major factor in the uplift of the Himalayan mountain range. The evidence for the separation of the Indian subcontinent from Gondwanaland, for its long journey from the southern hemisphere into the northern hemisphere, and for its eventual incorporation into what is now Asia, is based upon various lines of evidence, particularly within the fields of geophysics and geology. And it must be admitted that such evidence is convincing to the utmost degree.

Any theory, however, if it is to be viable, must satisfy all of the aspects of that theory. The usual reconstructed picture of peninsular India moving as an isolated island along a great circle through thousands of kilometers, from a position considerably below the equator to a new position somewhat above the equator, has been viewed with pleasure and equanimity by many geologists and geophysicists, because it explains very nicely certain structural features peculiar to this part of Asia. But how does the concept of the Indian peninsula as a drifting island during one phase of geologic history accord with the evidence of the fossils—particularly the remains of land-living animals? Is the drifting island concept compatible with the nature of the fossils found on that supposed island?

This is important, because the fossils are hard evidence that cannot be denied. And any theory or part of a theory that runs counter to the paleontological evidence must be revised or accommodated in some fashion to take account of the fossils. It is the purpose of this paper to examine the known Mesozoic vertebrate faunas of peninsular India, to see how they accord with the general notion of a drifting Indian island, or perhaps more properly, how the idea of such a drifting island accords with the fossils contained within it.

At this place I wish to acknowledge with gratitude the helpful criticism of this paper and advice concerning it, offered by Dr. David H. Elliot, Director of the Institute of Polar Studies of The Ohio State University, Columbus, Ohio. Also I wish to acknowledge much help and many kindnesses from paleontological colleagues in India, who enabled me to obtain some first-hand acquaintance with the Mesozoic geology of the sub-continent. Particular thanks are due to members of the Geological Studies Unit of the Indian Statistical Institute, and to officers of the Geological Survey of India.

Finally, I wish to express my satisfaction at being invited to contribute to this volume in honour of Dr. Orlov, whom it was my privilege to know as a colleague and personal fiiend.

THE POSTULATED NORTHWARD JOURNEY OF PENINSULAR INDIA

Before turning our attention to the fossils, it may be well to review very briefly the ideas that have been advanced concerning the drifting of peninsular India from a rifting Gondwanaland to its collision with Asia. What did such a journey entail, in distance and in time?

There is widespread agreement among the many authorities who have worked in detail on plate tectonics and continental drift that when Gondwanaland was an undisturbed supercontinent in Permian time, what is now the Indian peninsula occupied a position between Africa and Madagascar on the west, and Antarctica on the south and east. In short, India has been viewed as a great wedge, in actual contact on the one hand with

Madagascar, which in turn was in contact with Africa, and on the other with Antarctica, the latter area also being in contact with Africa, to the southwest of the tip of the Indian block. According to this view there was an oceanic gap between the northeastern edge of the Indian block and the western border of Australia the Sinus Australis.

There is however a somewhat different view as to the position of India in Gondwanaland, set forth particularly by Ahmad in 1960 and 1961, and more recently endorsed by King, in 1972. According to the reconstruction of Gondwanaland as envisioned by these authorities, what was to become the Indian subcontinent occupied a position to the east of the usually assigned place, with a landmass eventually to become Iran interposed between the western border of India and Africa. Such a placement of India within Gondwanaland brings its eastern border against the western border of Australia rather than next to Antarctica, as is the case in the usual reconstructions. Ahmad and King favour this position for India because it brings the eastern end of the Himalayan mountain system in line with the mountains of New Guinea.

Such views of relationships within Gondwanaland are based, of course upon hindsight. As a matter of fact, the entity which we call Gondwanaland was in late Paleozoic time probably an uninterrupted continent of vast proportons, with no indications of the lines of weakness along which it would fracture and rift, to separate into several lesser parts.

But the lines of weakness were there, and the rifting of Gondwanaland began sometime during the course of Mesozoic history. It was during the long, time-consuming rifting of Gondwanaland that peninsular India appeared as the wedge-shaped land mass with which we are familiar. The northeastward movement of this Indian wedge then was facilitated by the seeming development of large transform faults on either side of the Indian plate, so that the subcontinent could make its journey unimpeded. Indeed, the Indian plate has been envisaged as gliding among these faults or megashears in a rather independent manner, without the grinding interaction between it and contiguous plates that seemingly has been so general during the movements of tectonic blocks. In this way India migrated northeasterly toward its eventual junction with the Asiatic mainland· Assuming that this presents a reasonably accurate account of the migration of India, let us now turn our attention to the length of the journey.

Dietz and Holden (1970) in their reconstruction of Permian Gondwanaland, would place the Indian segment at about between south latitudes 40 degrees and 65 degrees. Moreover, they would place the tip of India at about 40 degrees east longitude, as contrasted with its present position of 78 degrees. Thus, in travelling from this porition to its present location, the Indian plate would have travelled about 8000 kilometers, at least, which is quite a journey.

Other authors may differ somewhat from Dietz and Holden in their views as to the paleolatitude of the Indian portion of an unbroken Gondwanaland, but the differences are not great. Generally speaking, what was to become the Indian peninsula is placed well within middle to high middle southern latitudes of the Paleozoic world, so that if this position is accepted, one must perforce accept the premise that peninsular India made a very long journey from its original to its present location. Consequently, within the framework of plate tectonic theory one can hardly avoid a figure on the order of 8000 kilometers for the northward migration of India.

When did this long journey of a subcontinent take place? Dietz and Holden consider it as having been initiated some 20 million years before the close of Triassic time, and continuing through the Mesozoic and into the Cenozoic, when the Indian peninsula finally collided with Asia. Thus, they show India at the end of the Triassic as a drifting island, separate from Antarctica and to the east of what was to become Madagascar and with its southern tip somewhat below south latitude 50 degrees. At the end of the Jurassic it is placed to the east of the northeastern border of Africa, its southern tip being somewhat north of south latitude 40 degrees. And at the end of the Cretaceous it is depicted as with its southern tip on the thirtieth parallel, south. According to these authors, therefore, the Indian island was moving north during much of the extent of Mesozoic time, having covered perhaps 3500 kilometers or more of its journey.

There are however, differences of opinions with Dietz and Holden as to the time when peninsular India broke away from Gondwanaland. Tuzo Wilson (1963) for example, shows the Indian segment as still an integral part of Gondwanaland "some 150 million years ago", which would have been in late Jurassic time. He places the initial rifting of Gondwanaland as having ocurred shortly before the beginning of the Cretaceous period.

A very similar view was expressed by Smith and Briden (cited in Hallam, 1973) who showed the southern continents in close apposition in early Cretaceous times "immediately prior to the break-up of Gondwanaland." Elliot, in 1972, indicates Gondwanaland as having been intact in late Jurassic time, with the break-up presumably beginning during the early Cretaceous. By mid-Cretaceous time, accordingly to this author, a separation had taken place between the southeastern border of Africa and Antarctica.

An even later separation of India from Gondwana land is seen by Laughton, Sclater and McKenzie (1973), who consider the north-ward movement of India to have taken place "during the Late Cretaceous and Early Tertiary." (p. 211).

Sclater and Fisher (1974) have quite recently indicated that the rifting of India from its junction with Antarctica and Australia took place between 100 million and 80 million years ago—that is in the late Cretaceous. They show the Indian subcontinent as being well separated from the still conjoined Antarctic-Australian landmass at the 80 MYBP stage (p. 699).

So it is that certain authorities would initiate the northward journey of India at about the beginning of the Cretaceous period, or even later. If this should prove to be the case, the drift of India across some 60 degrees of latitude would necessarily have been much more rapid than if the journey had occupied a significantly longer span of time, as postulated by Dietz and Holden.

Having presented this review of the several propositions that have been made concerning the original position of India within an unbroken Gondwanaland, the course of the drift of an Indian island (if indeed it was an island) to the north, and the timing of that drift, we may now turn to the fossils, to see if the concept of a drifting Indian island is truly in accord with these remains of ancient land-living animals. The evidence here to be examined is that of Mesozoic tetrapods (amphibians and reptiles) in peninsular India.

THE TRIASSIC TETRAPODS OF PENINSULAR INDIA

Triassic tetrapods in peninsular India are contained particularly within three successive faunas, from the Panchet, Yerrapalli and Maleri formations respectively. The Panchet beds are well exposed in the Raniganj coalfield about 200 kilometers northwest of Calcutta; the Yerrapalli and Maleri beds occur along the Pranhita-Godavari rivers, in the middle of the peninsula, to the south of Nagpur. The Panchet sediments are of early Triassic age, as are the somewhat later Yerrapalli beds. The Maleri Formation is of late Triassic age. Fossils have also been found in the Mangli beds of the Godavari region, correlative with the Panchet Formation, and in the Tiki beds of the Son Valley, correlative with the Maleri Formation.

The most abundant fossils from the Panchet Formation are those of the dicynodont reptile, *Lystrosaurus*. Some fine skulls and skeletons of this reptile are known from India, and these have been identified by Tripathi and Satsangi (1963) as *Lystrosaurus murrayi*, *L. platyceps* and *L. maccaigi*, species characteristic of the Lower Triassic, Middle Beaufort beds of South Africa. In addition they name a new species, *Lystrosaurus rajurkari*. Other reptiles from the Panchet Formation include fragmentary specimens of the thecodont, *Chasmatosaurus* (more properly *Proterosuchus*), and perhaps some remains of a procolophonid, one of the cotylosaurs. *Chasmatosaurus* or *Proterosuchus* and *Procolophon* are quite characteristic of the Middle Beauforts of South Africa, in association with *Lystrosaurus*. Labyrinthodont amphibians, as yet inadequately known, and fishes, as well as fresh-water invertebrates are known from the Panchet beds.

The very close resemblance of the Panchet fauna to the *Lystrosaurus* fauna of South Africa needs no labouring at this place. In both regions *Lystrosaurus* is by far the most common fossil. In both regions the sediments containing the fossils are most definitely of continental aspect. The fossil and sedimentary evidence thus point to a very close relationship between peninsular India and southern Africa in early Triassic time—a relationship made all the more striking because of the identity of certain species within the two now widely separated regious.

The *Lystrosaurus* fauna, so characteristic of the Lower Triassic beds of South Africa and repeated, so far as it is known, in the Indian peninsula, is also present in Antarctica, where again there is an identity of species, not only within the genus *Lystrosaurus* but also in other genera as well, such as the cotylosaur *Procolophon* and the theriodont reptile, *Thrinaxodon*.

The essential sameness of the Lower Triassic reptilian faunas in India, South Africa and Antarctica, indicates that these regions probably were geographically close to one another at the time Gondwanaland was an undisturbed continent. The *Lystrosaurus* fauna almost surely was a single vertebrate assemblage occupying a continuous range—a range subsequently fragmented by rifting. Therefore the evidence of the *Lystrosaurus* fauna favours a reconstruction of Gondwanaland in which peninsular India is in contact with Africa on the one side and Antarctica on the other, rather than the re-construction favoured by Ahmad and by King that would place India away from Africa and Antarctica and in contact with Australia.

The Yerrapalli Formation, consisting of red beds exposed in the Godavari Valley, has yielded a fauna containing two large dicynodont reptiles, *Wadiasaurus indicus* and *Rechnisaurus cristorhynchus*, a cynodont—one of the very advanced mammal-like reptiles, and a thecodont, perhaps an erythrosuchid, as well. In addition there is a labyrinthodont amphibian, *Parotosaurus rajareddyi*, and lungfish remains. Again we see a fauna of definite continental aspect with close relationships to South Africa. The dicynodonts of the Yerrapalli generally resemble *Kannemeyeria*, a characteristic Upper Beaufort reptile of the *Cynognathus* Zone of South Africa, an horizon directly above the Middle Beaufort *Lystrosaurus* Zone on that continent. Moreover, the cynodont and the thecodont reptiles of the Yerrapalli point to close connections with the African *Cynognathus* Zone. *Cynognathus* Zone type reptiles have been found in Argentina, as well. The labyrinthodont, *Parotosaurus*, is a widely distributed genus, found not only in India, but also in Africa, Australia, Europe and North America.

So it is that the vertebrate fauna of the Yerrapalli Formation continues the close ties to Africa, so apparent in the fossils from the Panchet beds. It is reasonable to think that the Yerrapalli formation is correlative with the South African *Cynognathus* Zone—that it represents a Lower Triassic stage immediately successive to the Panchet beds in India, just as the *Cynognathus* Zone is successive to the *Lystrosaurus* Zone in Africa.

In short, during early Triassic time the region of peninsular India was an integral portion of Gondwanaland. The journey to the north had not as yet begun.

The Maleri Formation of the Pranhita-Godavari Valleys is rather similar to the underlying Yerrapalli beds in composition and colour (both formations being fluviatile red beds), but it contains a fauna markedly different from the Lower Triassic faunas that have been reviewed. For the Maleri fauna consists of a lungfish, a subholostean fish and a fresh-water pleuracanth shark, a large labyrinthodont amphibian, a rhynchosaur, a large thecodont—a crocodile-like phytosaur, and perhaps two pseudosuchian thecodonts, one small and one large. Some small dinosaur remains also have been identified from the Maleri Beds. This is clearly an Upper Triassic assemblage, with much more cosmopolitan affinities than are to be seen in the Panchet and Yerrapalli faunas.

The labyrinthodont, for example, has been described as *Metoposaurus maleriensis*. The metoposaurs, as exemplified by the genus *Metoposaurus*, were among the last of the labyrinthodont amphibians, and are typical of the Upper Triassic of central Europe and North America. This faunal link between peninsular India and lands far to the north is strengthened by the presence of the phytosaur, *Phytosaurus maleriensis*. In this connection it should be noted that fragmentary but identifiable phytosaur bones have been found in the Upper Triassic of Madagascar, once again a point in favour of a ligation between Africa and peninsular India within the early Mesozoic Gondwanaland continent.

The small pseudosuchian would seem to be related to similar reptiles found in North America and Europe, while the large pseudosuchian was compared by von Huene (1940) to *Sphenosuchus* of the Upper Triassic Stormberg beds of South Africa.

The small dinosaur bones from the Maleri Formation represent a coelurosaurian theropod, not unlike *Coelophysis* from North America, and the recently described genus, *Syntarsus* from Rhodesia. As in the case of the metoposaur and the phytosaur, we see here a northern element in the Maleri fauna, but one that may be present in Africa as well.

Finally, one of the very interesting reptiles in the Maleri fauna is the rhynchosaur, *Paradapedon huxleyi*. This strange reptile, with tooth-like premaxillary bones and tooth studded plates in the sides of the jaws, finds its counterparts in *Hyperodapedon* from the Upper Triassic of Scotland, in *Scaphonyx* from the Upper Triassic of Brazil and to a lesser degree in *Stenaulorhynchus* from the Triassic Manda beds of east Africa. The Indian form is particularly close to the rhynchosaurs from Scotland and from Brazil, which would suggest possible influxes from the north and west, in all likelihood through Africa.

Therefore, the Maleri fauna contains elements with far-flung relationships-particularly to Africa, and perhaps through Africa to the South American segment of Gondwanaland, as well as to Laurasia to the north. It seems quite obvious that in late, as well as early, Triassic time peninsular India was not a drifting island; its connections with other parts of the world by way of Africa were firm.

THE JURASSIC TETRAPODS OF PENINSULAR INDIA

Within the past decade or so a veritable graveyard of large dinosaur bones has been excavated in the Lower Jurassic Kota Formation of the Pranhita-Godavari Valley. The dinosaur bones so procured represent a large sauropod, and are unique in being the oldest indications of this line of dinosaurs in the fossil record. The Kota dinosaur shows quite clearly that sauropod dinosaurs had appeared and had become giants by the beginning of Jurassic history. This dinosaur, designated as *Barapasaurus tagorei*, obviously is very close to the gigantic sauropods of late Jurassic age, some of which are prominent in the Upper Jurassic Tendaguru Formation of Tanzania.

It is significant that *Barapasaurus* was found in the Kota at an horizon below sediments containing such semionotid fishes as *Tetragonolepis*, *Dapedium* and *Lepidotes*, well known genera present in the Triassic of Europe. Thus the Lower Jurassic age of *Barapasaurus* can be established beyond any reasonable doubt.

One other reptile is at present known from the Kota beds, a pterosaur, designated as *Campylognathoides indicus*. This small flying reptile shows affinities with Lower Jurassic forms of the same genus from Europe.

The pterosaur of the Kota, so closely related to European forms of early Jurassic age, might be regarded as equivocal evidence concerning the continental relationships of peninsular India at this stage of earth history. After all, pterosaurs could fly across water barriers, but probably they did not cross very extensive oceans. But the huge sauropod bones present a clear and definitive picture. They constitute unmistakable evidence that a giant dinosaur inhabited this portion of Gondwanaland when it still had overland connections with other parts of the ancient continent.

Once again, the connection very possibly was with

Africa. Recently Raath (1972) has described a putative sauropod predecessor, from the Triassic-Jurassic boundary in Rhodesia. Other early sauropods, known for the most part from fragmentary materials, are *Rhoetosaurus* from the Middle Jurassic Walloon Series of Queensland, Australia, and *Amygdalodon* from possible Middle Jurassic beds in Patagonia.

So it would seem that during the opening phases of Jurassic history peninsular India was still a land-locked part of Gondwanaland.

THE CRETACEOUS TETRAPODS OF PENINSULAR INDIA

Dinosaur bones of Upper Cretaceous aspect have been known from peninsular India for many years. Specifically these are fossils from the Lameta Formation of Madhya Pradesh, first noted as long agoa s 1921. The Lameta dinosaur fauna was summarized by von Huene and Matley in 1933, but many of the names proposed by these authors have been regarded as doubtful by White in 1973, although they were not questioned by Romer in 1955. Whether or not the names are valid, it is evident that Upper Cretaceous dinosaurs of various kinds were present in central India during the final stages of Mesozoic history.

The Lameta dinosaurs would seem to be small coelurids (*Jubbulpuria*, *Compsosuchus* and *Laevisuchus*), ornithomimids (*Ornithomimoides*) and large, carnivorous megalosaurs (*Dryptosauroides* and *Orthogoniosaurus*), this last genus described by Das-Gupta in 1933. In addition there is a nodosaur or armored dinosaur, *Lametasarus indicus*, described by Matley in 1923.

Coelurids, ornithomimids, megalosaurs and nodosaurs are all found in the Upper Cretaceous in various parts of the world, but the ornithomimids, or ostrich dinosaurs, are limited to this portion of the geologic column. Consequently there is not much doubt as to the late Cretaceous age of the Lameta beds.

Although the Lameta dinosaurs are not as completely preserved as would be desirable, they are sufficiently well known to show their relationships to Upper Cretaceous dinosaurs in other parts of the world. All of the dinosaurian groups represented in the Lameta Formation are of cosmopolitan distribution; therefore the exact connection of peninsular India to continental masses in the late Cretaceous is not so clear as was the case for the Triassic and Jurassic, as indicated by tetrapods of the subcontinent. It is obvious, however, that Cretaceous India was connected to other lands; it definitely was not an isolated, drifting island. If the principal Cretaceous connection for peninsular India was with Africa, the final break-up of Gondwanaland had not as yet taken place.

THE MESOZOIC POSITION OF PENINSULAR INDIA

From this brief review of the known Triassic, Jurassic and Cretaceous tetrapods of peninsular India, it seems evident that what eventually was to become the subcontinent was firmly connected to other landmasses during much if not all of Mesozoic time. Otherwise, how is one to account for the land-living amphibians and reptiles, the fossil remains of which are well documented in central India? Since the occurrences of these Mesozoic tetrapods are beyond dispute how then is the supposed northward migration of India across thousands of kilometers of latitude to be accommodated to the presence of the fossils? Several possibilities may be considered.

(1) Peninsular India was never a part of Gondwanaland, but rather was a permanent part of the Asiatic continent, with access for the exchange of faunal elements with other portions of Laurasia.

(2) Peninsular India broke away from Gondwanaland during Triassic time, to move northward during the Mesozoic Era, but this movement was accomplished by sliding along the eastern edge of Africa in a manner similar to the present northwestward movement of the Pacific Plate against the North American Plate—thus ensuring avenues of intercontinental migration between Africa and India.

(3) Peninsular India broke away from Gondwanaland after early Jurassic time, to make the journey to Asia in the interval between about the middle of the Jurassic and the latter part of the Cretaceous, thus ensuring a contact with Africa through the early Jurassic and establishing a contact with Asia during late Cretaceous time.

(4) Peninsular India did not break away from Gondwanaland until very late Cretaceous time, and then drifted from its original position to its collision with Asia in the interval between about the end of Cretaceous and early to middle Cenozoic time.

These possibilities may be examined in sequence.

As for the first proposition, it would certainly accord with the former concept of fixed continents. Or it might be envisioned as a possibility, if one is to assume under the plate tectonic theory that India was never a part of Gondwanaland. However, the geophysical evidence does not support such an assumption. Moreover, on the basis of such an assumption, it is difficult to explain the remarkable faunal similarities between early Triassic India Africa and Antarctica. Perhaps India drifted as an island from Gondwanaland to Asia during middle Triassic time, but this does not seem very probable; it would imply a rapidity of plate motion out of line with our present knowledge concerning rates of drift.

The second of the above proposals is a modification of the Dietz-Holden model for the movement of India between Gondwanaland and Asia. This possibility was set forth by the present author in 1973 as a means for explaining the presence of land-living Mesozoic tetrapods in the Indian peninsula. If the western border of India ground its way along the eastern border of Africa there would be ample opportunity for faunal exchanges between the subcontinent and the rest of the world during Mesozoic time. Such an explanation, however, overrules the geophysical evidence, which indicates large transform faults on each side of India to facilitate its northward movement. It is a case of sacrificing what has been learned from sea-floor studies in order to account for the presence of Mesozoic tetrapods in the peninsula.

Let us therefore accept the evidence of the transform faults, which would have made possible a relatively smooth and perhaps a very rapid migration of the Indian plate from south to north. Is it possible that the journey took place between the early Jurassic and the late Cretaceous? as suggested by the third of the above-listed possibilities There are no tetrapod fossils representatives of this time interval as yet known in the peninsula. On the basis of lack of any fossil evidence, it is possible to envisage the movement of the Indian plate as having taken place at this time. The interval here being considered might embrace a span of perhaps 80 million years. If the Indian plate were to move at an average rate of 10 centimeters per year, it would traverse the calculated distance of 8000 kilomters between its original and its present positions in just 80 million years, and this fits the formula very nicely.

This suggestion is partially in accordance with Hallam (1967) who, after considering the views of many authorities who had worked on the problems of drift, suggested a rather late date for the separation of peninsular India from Gondwanaland. "The indications of free 'intercontinental' communication of land and neritic faunas as deduced from strong faunal affinities suggest that the continents may not have begun to drift apart until the Cretaceous.... The case needs arguing more fully, however, for the Indian Ocean, since it has been proposed that this began to open up in the Jurassic..." (p. 227). "Active drifting apart of the components of Gondwanaland was probably well under way by mid-Cretaceous times..." (p. 229). Such a date for the break-way of India and other Gondwanaland fragments would be generally in accord with the pattern envisaged by Elliot (1972).

Hallam presents his reconstruction of the southern continents in late Senonian time, showing peninsular India as an island to the east of Africa and somewhat north of Madagascar, and presumably still far removed from Asia. This is all very well, except that the Senonian is getting well into the latter part of the Cretaceous, when we know that various dinosaurs inhabited peninsular India. Therefore, if India were to collide with Asia sufficiently early to allow late Cretaceous dinosaurs to enter the subcontinent, the remainder of the journey would necessarily have been extremely rapid.

All of this might be invalidated, of course, by the discovery of Upper Jurassic or Lower Cretaceous land-living tetrapods in the Indian peninsula.

Which brings us to the fourth of the possibilities outlined above-namely that the Indian peninsula did not break away from Gondwanaland until almost the end of Cretaceous time, and made its journey from south to north in the interval between the Cretaceous and the early to the middle Cenozoic Era. The retention of the peninsular region within Gondwanaland throughout the extent of Mesozoic time would explain very nicely the presence of Triassic, Jurassic and Cretaceous land-living tetrapods, especially reptiles, on the subcontinent. Also, such a late presence of what was to become the Indian peninsula within Gondwanaland would not be affected by any future discoveries of late Jurassic or early Cretaceous reptiles in central India.

Furthermore, this late break-up of Gondwanaland is more or less in accordance with the model as proposed by McKenzie and Sclater in their 1973 paper on the Evolution of the Indian Ocean. These authors would have India breaking away from Gondwanaland about 75 or 80 million years ago, which would be at some stage in the late Cretaceous. It also accords with the subsequent proposal of Sclater and Fisher (1974), mentioned above.

With the possible exception of a questionable Moeritheriid sacrum from Kutch, assigned to the middle Eocene (although moeritheres in Africa do not appear before the late Eocene), there seem to be no fossil of land-living mammals in peninsular India until we reach rocks of early Miocene or Burdigalian age. Of course this void in the fossil record may not reflect an actual absence of such animals in India during early and middle Cenozoic time; it may be owing to the erosion of mammal-bearing sediments or to the accidents of collecting. Supposing for the moment, however, that it indicates a real absence of land-living tetrapods in India during that particular time interval.

If, then, we assume that the Indian subcontinent broke away from Gondwanaland about 10 million years before the end of Cretaceous time, and that it collided with Asia perhaps 40 million years after the advent of Cenozoic time, that would allow a 50 million year interval for the movement of the Indian plate from Gondwanaland to Asia. (This figure is based upon the allotment of 10 million years to the Paleocene, 18 million years to the Eocene, 10 million years to the Oligocene, with a 2 million year "overrun" into the Miocene.)

A fifty million year interval for a journey of 8000 kilometers would entail rather rapid drift—more rapid than that proposed for the Jurassic-Cretaceous journey, suggested above. McKenzie and Sclater have suggested that during a part of the journey north the Indian plate may have travelled at a rate of 7.5 centimeters per year, while during another part of the journey the rate may have been as much as 16 centimeters per year. Although the 16 centimeter figure is high, it is not excessive. "Even faster rates, however, have been measured on the present spreading ridge in the southeast Pacific, where the plates are moving apart at nearly 20 centimeters per year." (McKenzie and Sclater, p. 69).

With such considerations for a background, it may be calculated that if India made the 8000 kilometer journey from its original to its present position in the proposed 50 million year interval between late Cretaceous and early Miocene time, the average rate would have been on the order of 16 centimeters per year, which is the high figure proposed by McKenzie and Sclater. Of course the plate may have moved even faster for a part of the journey and more slowly for another part. Nevertheless, the time interval of 50 million years is sufficient to account for the journey of the Indian peninsula, carrying its cargo of Mesozoic fossils like a Viking funeral ship (to use the simile suggested by McKenna, 1973) to an ultimate beaching on what were then the southern shores of Asia.

This is perhaps the best explanation for the presence of Mesozoic land-living tetrapods in peninsular India, an explanation that may be completely negated if in the future early Cenozoic mammals are discovered in central India. But for the present it gives a valid basis for the presence of Mesozoic reptiles and amphibians in central India, against which the northward drift of the subcontinent as an island between bounding transform faults may be equated.

CONCLUSIONS

The presence of Mesozoic land-living amphibians and reptiles in central India can be correlated with the concept of the Indian subcontinent drifting as an island, bounded by transform faults, from Gondwanaland to Asia, if such drift is considered to have taken place at a fairly rapid, but not unreasonable rate. The drift may have occurred between middle Jurassic and middle Cretaceous time, an interval as yet unrepresented by terrestrial tetrapods in central India, or between late Cretaceous and early to middle Cenozoic time, again in which the fossil record is equally devoid of land-living vertebrates. It is here proposed that the second interval —between the Cretaceous and the mid-Cenozoic may be the correct interpretation. It is in accord with the thinking of those authorities, who upon the basis of geophysical evidence, consider the separation of peninsular India from Gondwanaland to have occurred at a very late date within Mesozoic time.

Of course if fossil tetrapods are found in central India in Upper Jurassic and Lower Cretaceous sediments, or in Lower Cenozoic sediments, one or the other of the above solutions must be abandoned. If fossils are found both in Upper Jurassic-Lower Cretaceous and Lower Cenozoic beds, then some serious rethinking must be undertaken by those who base their conclusions on the geophysical evidence. The fossils are there-their presence cannot be disputed.

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